State of California
AIR RESOURCES BOARD

STAFF REPORT: INITIAL STATEMENT OF REASONS FOR RULEMAKING

PUBLIC HEARING TO CONSIDER AMENDMENTS TO THE CURRENT INBOARD AND STERNDRIVE BOAT REGULATIONS

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This report has been reviewed by the staff of the California Air Resources Board and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Air Resources Board, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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EXECUTIVE SUMMARY

On June 8, 2001, the Air Resources Board (Board or ARB) adopted amendments to the spark-ignition recreational marine engine regulation to include exhaust standards for inboard and sterndrive pleasurecraft beginning with the 2003 model year. Inboard and sterndrives are used primarily for recreational purposes. Their engines are typically derived from V-8 or V-6 automotive spark-ignition truck engines. Inboard engines typically drive a long, straight propeller shaft. Sterndrive engines are situated inboard in the extreme rear-end of the boat and drive an external transmission.

The resulting 2001 regulation capped exhaust emission levels at 16.0 grams per kilowatt-hour (g/kW-hr) for combined hydrocarbon and oxides of nitrogen (HC+NOx) emissions through 2006, but then required a more stringent catalyst-based standard (5.0 g/kW-hr) to be phased-in between 2007 and 2009. The amendments also required the incorporation of marine on-board diagnostics (OBD-M) on catalyst-equipped engines to help ensure that emission control systems continued to work properly throughout an engine's useful life. Staff estimates that the statewide summer weekend emissions inventories[1] of NOx and HC for inboard and sterndrive engines will be reduced by 44.8 tons per day and 12.0 tons per day, respectively, in 2020 as a result of the Board's action. The Board also adopted in-use durability requirements and recall/warranty provisions in 2001 that invested California with full enforcement authority to ensure the regulatory compliance of inboard and sterndrive engines throughout their useful lives.

On October 28, 2004, staff returned to the Board to present the findings of a test program that it had sponsored to evaluate catalytic converter safety and durability in a fresh-water environment (SwRI 2004). At the end of testing, the contractor, Southwest Research Institute (SwRI), determined that no heat-related safety issues arose during the 480 hours of operation (cumulatively, over 1,900 hours). The contractor also determined that the catalysts continued to function efficiently throughout the test program with three managing to remain under the 5.0 g/kW-hr standard for HC+NOx. The Board accepted staff's findings, but directed staff to keep an open dialogue with the marine industry and to follow its progress in developing the technology to comply with the existing Inboard/Sterndrive regulation.

In meeting with industry as the Board directed, staff became aware of several concerns regarding feasibility and the timing of the regulation. Specifically, these concerns are 1) the effects of a saltwater environment on emission control components such as catalytic converters and oxygen sensors, 2) the difficulty and expense of equipping and testing large horsepower engines with catalytic converters, 3) the feasibility of monitoring the catalytic converter as required by the OBD-M requirements, and 4) insufficient lead time to equip 45 percent of engines with catalytic converters in 2007, the first year of the standards phase-in.

[1] Estimated 2020 benefits are based on July 2005 off-road emissions inventory data, and differ slightly from earlier calculations due to modeling refinements after the 2001 adoption of the existing regulation.

The following report presents staff's proposal to amend the existing Inboard/Sterndrive regulations. To address industry's concerns regarding the effects of salt-water and OBD-M, ARB has begun another test program to evaluate the emission control performance of inboard and sterndrive engines that are operated on the ocean. The data collection phase of this program is scheduled to be completed by the end of October 2005, and staff plans to include the findings of the program, as available, in its presentation to the Board at the November 17-18, 2005, Board Hearing. Should the findings conclusively demonstrate technical problems with the existing regulation, staff will propose to the Board further amendments to the regulation to resolve the issues at hand. To address the concerns regarding high-power engines and lead-time, staff is proposing to provide marine engine manufacturers with a choice of implementation schedules for complying with Inboard/Sterndrive standards. This is intended to reduce the burden of compliance on the industry by giving each manufacturer an opportunity to choose a deployment strategy best suited to its production roll-out goals, while preserving the emission benefits of the existing Inboard/Sterndrive regulation. Staff's proposed amendments would also permit averaging emissions from engines with rated power greater than 373 kW (500 horsepower) with those less than 373 kW beginning with the 2009 model year.

One of the implementation options proposed by staff would allow engine manufacturers to replace the 2007-2009 phase-in requirements with full compliance of all models in 2008. Although each implementation option would result in at least the same degree of emission benefits as the existing regulation, this option has the potential to increase benefits depending on the approach of the manufacturer.

The cost-effectiveness of the proposed amendments is the same or better than the current regulation, which is a favorable \$2.08 to \$3.39 per pound of HC+NOx reduced. Presumably an engine manufacturer would use the new option only if it resulted in no increase in cost. The emissions reduction of the proposed option will be at least as great as in the current regulation. The cost-effectiveness of the proposal is equal to or superior to the existing regulation.

Based on these conclusions, staff recommends that the Board adopt this proposal.

1. INTRODUCTION

This report describes the rationale and details of staff's proposal to amend California's existing regulations for new spark-ignition inboard and sterndrive pleasurecraft. On October 28, 2004, at a Public Board Meeting, the Air Resources Board (Board or ARB) directed staff to continue dialogue with the regulated marine industry regarding technological challenges and developments and to revisit the regulation should it become desirable to make amendments (ARB 2004). As a result, several issues have arisen regarding the implementation timeframe for catalyst-based standards and the compliance of marine engines rated at power levels exceeding 373 kW (500 horsepower). The changes proposed herein are meant to address these concerns and to provide additional opportunities for reducing the emission inventories of combined hydrocarbon and oxides of nitrogen (HC+NOx) in California.

2. BACKGROUND

This section provides information on the history of emissions control for recreational marine pleasurecraft, a citation of California's authority to set standards for off-road mobile sources including recreational marine pleasurecraft, the current emissions inventory for Inboard and Sterndrive engines, existing recreational marine regulations, and the steps taken to make the public and stakeholders aware of staff's proposal to amend California's current regulations.

2.1. History

Only in recent years has government regulatory activity been undertaken to control exhaust emissions from spark-ignition recreational marine engines. The United States Environmental Protection Agency (U.S. EPA) first promulgated exhaust emission standards for personal watercraft and outboard boat engines in 1996 (U.S. EPA 1996). However, revised emissions inventory modeling showed that the benefits of the federal rulemaking were not sufficient to meet California's air quality goals and State Implementation Plan (SIP) requirements. Therefore, ARB adopted exhaust emission regulations for spark-ignition recreational marine engines in 1998 (ARB 1998a). The Board approved regulations that accelerated the 2006 federal standards to begin in 2001 in California. The regulations also set more stringent standards for these engines to be implemented in 2004 and 2008. By 2008, personal watercraft and outboard engines in California will meet exhaust emission standards that are numerically 65 percent less than federal exhaust emission standards.

On July 26, 2001, the Board amended the spark-ignition marine regulations (Title 13, California Code of Regulations, section 2440 et seq.) to include inboard and sterndrive engines (ARB 2001). Although personal watercraft and outboard boats dominate the emissions inventory with respect to recreational marine engines, ARB modeling showed that inboard and sterndrive engines also contributed significantly to ozone-forming emissions in California.

Accordingly, manufacturers of inboard and sterndrive engines have been required to demonstrate compliance with an HC+NOx exhaust emissions standard of 16.0 grams per kilowatt-hour (g/kW-hr) since the 2003 model year. This standard is equivalent to California's most stringent exhaust standard for engines used in personal watercraft and outboard boats, which, for those engines, is not required until 2008.

The existing inboard and sterndrive regulations also require compliance with a more stringent HC+NOx standard beginning in 2007 on a portion of engines. Since inboard and sterndrive marine engines are similar to automobile engines, for which a number of effective emission control technologies already exist, transference of automotive control technologies (catalysts specifically) to the marine sector makes a more stringent standard feasible. In fact, the majority of inboard and sterndrive engines with rated power less than 373 kW are almost exclusively General Motors or Ford truck engines that have been marinized[2] for use on lakes and the ocean. Accordingly, the Board adopted a 5.0 g/kW-hr HC+NOx standard for these engines, which was based on the demonstrated use of three-way catalytic converters and oxygen sensor feedback control.

2.2. Authority

In addition to more general grants of authority, the California Clean Air Act, as codified in Health and Safety Code section 43013, directs the ARB to regulate off-road mobile sources of emissions. Health and Safety Code section 43018 further mandates ARB "to achieve the maximum degree of emission reduction possible" from mobile sources of pollution in order to attain California's ambient air quality standards. These off-road mobile sources include, but are not limited to, marine vessels, locomotives, utility engines, off-road motorcycles, and off-highway vehicles. This regulation focuses on spark-ignition (gasoline) inboard and sterndrive marine engines, typically found in recreational boats such as ski boats or family fishing boats.

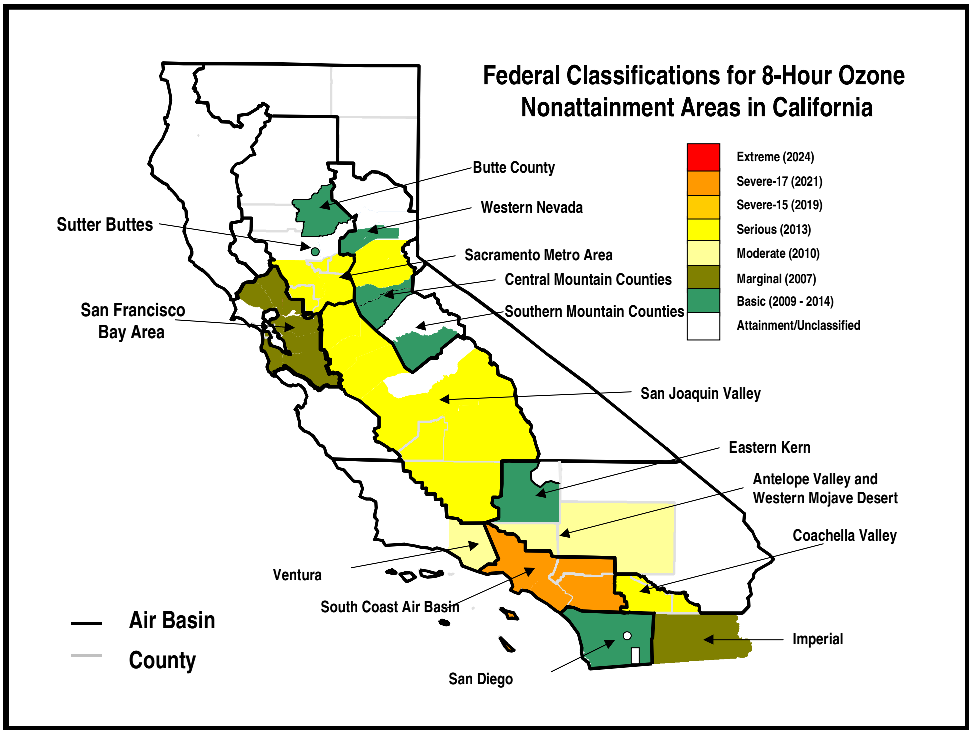
2.3. Need for Regulatory Action

The emission standards previously adopted by the Board significantly reduce the human health and environmental impacts of ground-level ozone. This section summarizes the air quality rationale for controlling inboard and sterndrive engines.

Figure 2.1 below identifies air basins and counties that are in non-attainment with the federal eight-hour standard for ozone.

[2] Marinization is the process of modifying an existing automobile engine to operate reliably in a marine environment. Some typical modifications include upgrading the composition of exhaust components to be more resistive against rust and corrosion, incorporating a water jacket within the exhaust manifolds to reduce temperatures, and providing better insulation for electrical contacts that might otherwise be exposed to corrosive sea water.

Figure 2.1
Eight Hour Ozone Non-Attainment Areas in California



Over 50 percent of California's air basins fall within this designation. Mobile sources currently[3] account for 47 percent of the total ozone precursors statewide. Recreational marine engines are responsible for about 4 percent of ozone precursors in the mobile source inventory and Inboard/Sterndrive spark-ignition engines represent 30 percent of the ozone precursors in the recreational marine inventory (Almanac 2005).

2.3.1. Ozone

Ground-level ozone is created by the photochemical reaction between NOx and ROG. Breathing ozone can trigger a variety of health problems including chest pain, coughing, throat irritation, shortness of breath, and congestion. It can worsen bronchitis, emphysema, and asthma. Ozone can also reduce lung function and inflame the linings of the lungs. Repeated exposure may permanently scar lung tissue.

Among those persons who may be most affected are people with compromised respiratory systems, the elderly, and children. Healthy people also experience difficulty breathing when exposed to ozone pollution. Because ozone forms in hot weather, anyone who spends time outdoors in the summer may be affected, particularly children, outdoor workers and people exercising. Millions of Californians live in areas where the federal ozone health standards are exceeded.

[3] Estimates are from the California Almanac of Emissions for the 2005 calendar year.

Ground-level ozone also damages vegetation and ecosystems. It leads to reduced agricultural crop and commercial forest yields, reduced growth and survivability of tree seedlings, and increased susceptibility to diseases, pests, and other stresses such as harsh weather. Ground-level ozone harms the foliage of trees and other plants, affecting the landscape of cities, parks and forests, and recreational areas. NOx also contributes to acid deposition and the overgrowth of algae in coastal estuaries.

2.3.2. NOx and Particulate Matter Relationship

Fine secondary nitrate particles are produced in the atmosphere from the NOx emitted by internal combustion engines. This type of particulate matter consists primarily of ammonium nitrate and represents about 25 percent of measured PM10 in the Los Angeles Basin (U.S. EPA 1997). The control of secondary nitrate PM will be critical in meeting California’s air quality attainment goals for the future.

2.4. Existing Regulations

The existing State, Federal, and International recreational marine standards are briefly discussed in this subsection.

2.4.1. 2003 and Later Inboard/Sterndrive Regulation

The current Inboard/Sterndrive regulation was adopted by the Board in 2001 and applies to all pleasurecraft utilizing new inboard or sterndrive engines beginning with the 2003 model year. The regulation prohibits the release of crankcase emissions directly to the ambient atmosphere, and it requires compliance with two phases of increasingly stringent exhaust emission standards. The first phase requires all engines to meet a 16.0 g/kW-hr HC+NOx standard on a corporate basis by sales-weighting engine family certification levels. The second phase requires engines to meet a more stringent HC+NOx standard of 5.0 g/kW-hr beginning on a portion of engines in 2007 and 2008, then on all engines beginning in 2009 and thereafter. Engine manufacturers have to certify at or below this standard without averaging across engine families. Further, manufacturers of marine engines rated greater than 373 kW (500 horsepower) do not have to comply with the regulation until 2009.

In addition, the current regulation established a durability period for engines certified to the 5.0 g/kW-hr NMHC+NOx standard. Emission levels would have to remain at or below the standard for at least 480 hours or for ten years (see Table 2.1). A certification test cycle (ISO 8178-4 E4) was adopted to verify that the engines meet the standard under the most representative operating conditions.

Table 2.1
Existing Inboard/Sterndrive Emission Standards

MODEL YEAR	POWER CATEGORY [kilowatts]	DURABILITY [hours]	16.0 g/kW-hr Averaged Standard NMHC[1]+NOx	5.0 g/kW-hr Fixed Standard NMHC[1]+NOx
2003 - 2006	kW ≤ 373	-	100%	-
2007			55%	45%
2008			25%	75%
2009 and later	ALL	480[2]	-	100%

Notes:
1 ARB standards are expressed as the non-methane component of hydrocarbon (NMHC)
2 The durability period may be expressed as either 480 hours or 10 years, whichever occurs first

The regulation requires certification and environmental labels to be attached to the engine and boat, respectively, to provide prospective engine owners, current engine owners, and enforcement personnel with information about the relative cleanliness of the engine. Beginning in 2007, inboard and sterndrive pleasurecraft complying with the proposed 5.0 g/kW-hr standard will receive a four star label to highlight the fact that they are the lowest emitting recreational marine vessels available (see Figure 2.2).

Figure 2.2
Marine Engine Consumer Labels

The current Inboard/Sterndrive regulation also provides Selective Enforcement Auditing (SEA), In-Use Compliance testing, and a defects warranty program to protect consumers against poor quality products and to ensure that the engines continue to perform as designed throughout their entire useful lives.

The regulation also requires inboard and sterndrive pleasurecraft to employ on-board diagnostics (OBD-M) on engines complying with the 5.0 g/kW-hr standard to continuously monitor emission control components for proper performance and to alert the vessel operator via a dashboard light or audio alert device after a malfunction has been identified. Among the major components to be monitored by the OBD-M system are the catalyst, oxygen sensors, solenoids, fuel system, and the on-board computer itself. The OBD-M system will make consumers aware when a component fails under the warranty period which in turn will provide incentive to have the problem corrected in a timely manner since the consumer will not be liable for the repair. Furthermore, it will facilitate the repair of the malfunctioning component by providing a detailed description of the problem to the service technician via a generic scan tool, and a confirmation that the repair has been performed correctly.

2.4.2. Federal Regulations

As previously mentioned, U.S. EPA promulgated regulations in 1996 for outboard and personal watercraft; however, this regulation did not apply to inboard and sterndrive pleasurecraft. In August 2002, U.S. EPA announced a proposed rulemaking (U.S. EPA 2002) primarily aimed at controlling evaporative emissions from spark-ignition marine engines (including inboards, sterndrives, personal watercraft, and outboards).

At the time this proposal was released, U.S. EPA did not propose exhaust emission standards for inboard and sterndrive engines. Instead, it wanted to collect more information and investigate further the application of catalysts; which would not only apply to inboards and sterndrives, but quite possibly to personal watercraft and outboard engines as well. However, as of the publication of this staff report, U.S. EPA has conveyed to ARB staff that it intends to promulgate exhaust emission standards equivalent to those required by California in addition to evaporative control standards when it publishes the final rule. Staff anticipates a final rulemaking from U.S. EPA sometime in early 2007.

2.4.3. Swiss (BSO) Regulations

Beginning in 1993, boat usage on Lake Constance, which borders Switzerland, Germany, and Austria, was contingent on the boat owner possessing certification from the boat/engine manufacturer stating that the engine(s) emit less than the “Stage 1” standards. The Stage 1 standards are 15.0 g/kW-hr for NOx and range from 4.0 g/kW-hr to 5.0 g/kW-hr for HC (depending on engine power). These apply to outboards and inboards, diesel or gasoline, commercial or recreational boats.

Effective January 1996 on Lake Constance, the standards became variable according to engine power rating. A typical 120 kW (165-horsepower) inboard or sterndrive engine is required to meet a 1.3 g/kW-hr standard for HC and a 3.7 g/kW-hr standard for NOx. High-power inboard and sterndrive engines (e.g., 300 kW / 400 horsepower) are required to meet a 1.0 g/kW-hr standard for HC and a 3.8 g/kW-hr standard for NOx.

2.4.4. European Regulations

The European Community (EC) is now developing recreational marine engine emission standards. For a 50 kilowatt two-stroke engine, combining the HC and NOx emission standards yields a total of 31.0 g/kW-hr. This is more stringent than California’s 2004 outboard standard of 38.0 g/kW-hr for a similar sized engine, but less stringent than

California's 2008 standards (16.0 g/kW-hr). For inboard and sterndrive engines, however, the EC standards are not as stringent as the BSO standards or California's existing standards.

2.5. Existing Emissions Inventory

Table 2.2 shows the statewide baseline inventories for the reactive organic gas (ROG[4]) component of hydrocarbon and NOx from inboard and sterndrive engines in 2007, 2010, and 2020. These baseline estimates are annual averages and include the effects of all currently adopted State and federally promulgated regulations. All emissions estimates are from the ARB's off-road emissions inventory database as of July 2005.

Table 2.2
Existing Inboard/Sterndrive Emission Inventories
Statewide Annual Averages

ENGINE TYPE	POLLUTANT	EMISSIONS INVENTORY[1] (tons per day)		
		2007	2010	2020
STERNDRIVE	ROG[2]	10.1	9.8	8.5
	NOx	11.6	11.4	10.3
	ROG[2]+NOx	21.7	21.2	18.8
INBOARD[3]	ROG[2]	8.2	8.0	6.7
	NOx	9.5	9.4	8.3
	ROG[2]+NOx	17.7	17.4	15.0
TOTAL	ROG[2]	18.3	17.8	15.2
	NOx	21.1	20.8	18.6
	ROG[2]+NOx	39.4	38.6	33.8

Notes:
1 These estimates take into account all previously adopted regulations for spark-ignition inboard and sterndrive engines
2 ARB inventory estimates are expressed as the reactive organic gas (ROG) component of hydrocarbon
3 This engine classification also includes recreational spark-ignition jet drive engines

From the table it is clear that ozone precursors from these engines are decreasing over time as a result of the Board's previous action. Between 2007 and 2020, combined ROG and NOx emissions decrease by over 4.5 tons per day. Still, this table only shows half the story. To provide the complete picture, Table 2.3 illustrates the emissions inventories for ROG and NOx from inboard and sterndrive engines during summer weekends. Recreational watercraft are used most frequently during summer months

[4] The terms "NMHC" and "ROG" are used synonymously throughout this report to represent the component of hydrocarbon most likely to form ozone. ROG is typically used to reflect inventory modeling parameters, and NMHC is typically used for emission standards.

when the temperature is hot and smog levels are high. Emission levels associated with summer weekend operation are approximately 260 percent higher than corresponding annual average levels due to increased boating activity during the summer months. This is especially relevant since the potential for ozone formation is highest during summer weekends.

Table 2.3
Existing Inboard/Sterndrive Emission Inventories
Statewide Summer Weekend

ENGINE TYPE	POLLUTANT	EMISSIONS INVENTORY[1] (tons per day)		
		2007	2010	2020
STERNDRIVE	ROG[2]	36.7	35.8	31.0
	NOx	42.3	41.4	37.5
	ROG[2]+NOX	79.0	77.2	68.5
INBOARD[3]	ROG[2]	29.8	29.1	24.4
	NOx	34.7	34.2	30.2
	ROG[2]+NOX	64.5	63.3	54.6
TOTAL	ROG[2]	66.5	64.9	55.4
	NOx	77.0	75.6	67.7
	ROG[2]+NOX	143.5	140.5	123.1

Notes:
1 These estimates take into account all previously adopted regulations for spark-ignition inboard and sterndrive engines
2 ARB inventory estimates are expressed as the reactive organic gas (ROG) component of hydrocarbon
3 This engine classification also includes recreational spark-ignition jet drive engines

This table shows that combined hydrocarbon and oxides of nitrogen will decrease by over 20 tons per day between 2007 and 2020 due to the Board's previous actions.

2.6. Public Process

In developing its proposal, staff has remained in close contact with the regulated marine industry in order to follow industry's progress regarding the 2001 regulation and to be kept apprised of any issues that might delay compliance efforts. The following provides a list of specific examples:

<u>2004 Public Board Meeting</u>
On October 24, 2004, staff presented its findings at an ARB Meeting in the San Joaquin Valley Unified Air Pollution Control District in Fresno, CA, on the freshwater catalyst demonstration program and reported on the status of the Inboard/Sterndrive rulemaking. The program was conducted between calendar years 2002 and 2004 for the purpose of demonstrating the safeness and durability of catalysts and other related emission control components in the marine environment. Staff's presentation also

brought out some of industry's concerns regarding the timeframe for introducing catalysts and demonstrating the compliance of engines with rated power levels greater that 373 kW. The National Marine Manufacturers Association (NMMA) expressed its desire to have ARB amend the regulation's implementation schedule such that instead of having the 5.0 g/kW-hr HC+NOx standard phased-in during model years 2007 through 2009, it should be fully implemented across product lines in 2008. Staff expressed a willingness to consider this amendment, but only so long as the overall emission benefits in 2007 and later could be maintained.

Industry also requested a regulatory amendment to allow corporate averaging to include engines with rated power levels greater than 373 kW. Currently, engines with rated power levels greater than 373 kW are exempt from the regulation through 2008. After 2008, however, unless these larger engines could be corporate averaged with the significantly more populous smaller engines, they would need to be equipped with catalysts to comply with the regulation, which is costly and difficult to verify emissions performance due to the lack of testing facilities capable of testing marine engines rated at power levels greater than 373 kW. Staff indicated it was amenable to the concept so long as the averaging methodology does not pose a competitive disadvantage to small volume manufacturers.

Industry also requested a revision to the on-board diagnostic requirements such that it would be split into two phases. The first phase, to begin in 2008, would not include catalyst monitoring, but would include all other monitors. The second phase would begin in 2012 and would include catalyst monitoring. Staff does not believe that industry's concerns merit delaying the OBD-M requirements as proposed. Sufficient flexibility is already built into the existing regulation to allow industry until 2012 to have implemented a fully functional and reliable catalyst monitoring system using proven technology transferred from the automotive sector (see subsection 4.2.1 for more details).

<u>Meetings with Marine Manufacturers</u>

In addition to frequent conference calls and meetings with NMMA, staff met individually with representatives from three of the six inboard and sterndrive manufacturers that currently certify engines in California between January 25 and February 9, 2005. The manufacturers were Indmar, Volvo Penta, and Mercury Marine. During each of those meetings staff heard the manufacturer's concerns regarding compliance with the existing catalyst-based standards (5.0 g/kW-hr) set to begin on a portion of production engines with the 2007 model year. These meetings were informative and helped guide the development of staff's proposed amendments to the existing regulations for inboard and sterndrive pleasurecraft.

<u>2005 U.S. EPA Authorization Hearing</u>

On February 28, 2005, U.S. EPA, at the request of NMMA, held a public hearing to evaluate the reasonableness of California's 2001 Inboard/Sterndrive rule before deciding whether or not to authorize California to regulate these engines independently of the federal government, which is allowed under provision of the Clean Air Act. Staff's presentation at the hearing, and in subsequent comments, clearly demonstrated that ARB met the obligation for receiving authorization, namely that California's regulations would be, in the aggregate, at least as protective of public health and welfare as the applicable federal standards, that California's standards for nonroad engines such as these are necessary as part of a program to address conditions in California, and that California's regulations are not inconsistent with applicable portions of the federal Clean Air Act (Authorization 2005). U.S. EPA, however, has still not reached a decision regarding the issuance of the requested authorization. While ARB believes U.S. EPA has no basis for denying California's request, U.S. EPA's timeframe for action on it is uncertain.

Meeting with Industry to Discuss Saltwater Test Program

On April 28, 2005, staff met with NMMA and representatives from several individual marine engine and boat manufacturers at the Southwest Research Institute (SwRI) in San Antonio, Texas, to discuss a saltwater demonstration program of inboard and sterndrive engines. The mutually agreed upon test program is currently underway and staff intends to present the results of that program, as available, to the Board at the November 17-18, 2005, Board Hearing.

3. SUMMARY OF PROPOSED REGULATIONS

The staff recommends that the Board amend sections 2111, 2112, 2441, 2442, 2444.2, 2445, 2446, and 2446, Title 13, California Code of Regulations, as set forth in Attachment 1: "Proposed Amendments to the California Regulations for New 2007 and Later Spark-Ignition Inboard/Sterndrive Pleasurecraft" and Attachment 2: "Proposed Amendments to the California Exhaust Emission Standards and Test Procedures for 2001 Model Year and Later Spark-Ignition Marine Engines" of this report.

Staff's proposed amendments to the existing regulation are meant to provide industry with additional lead-time for complying with the catalyst-driven 5.0 g/kW-hr HC+NOx exhaust standard while preserving the emission benefits of the existing regulation. The amendments would allow engine manufacturers to choose from two implementation options to comply with the Inboard/Sterndrive standards. This is intended to reduce the burden of compliance on the industry by giving each manufacturer an opportunity to choose a deployment strategy best suited to its production roll-out goals. The first implementation option proposed by staff allows manufacturers to certify to the identical standards and schedule required by the existing Inboard/Sterndrive regulations. The second implementation option allows manufacturers to replace the current 2007-2009 phase-in with full-compliance in 2008, one year earlier than currently required. Manufacturers choosing the second option would also be required to provide additional emission reductions of HC and/or NOx to compensate for the loss in emission benefits occurring in 2007. The following subsections discuss the major provisions of staff's proposal in further detail.

3.1. Applicability

The regulations as amended by this proposal would continue to apply to new spark-ignition inboard and sterndrive engines produced for sale in California for the 2007 model year and later, with exceptions provided for competition racing boats. Inboard and sterndrive engines with rated power levels greater than 373 kW would remain exempt from the amended regulations through the 2008 model year.

3.2. Definitions

Staff does not propose to add additional definitions to the regulations at this time; however, the dates in several definitions are proposed to be revised to correspond with the schedule of the implementation options that staff is proposing.

3.3. Emission Standards and Averaging

The existing Inboard/Sterndrive regulation requires manufacturers to comply with a 16.0 g/kW-hr HC+NOx exhaust emissions standard for model years 2003 through 2006, and then to phase-in engines meeting the 5.0 g/kW-hr HC+NOx standard at the rates of 45 percent, 75 percent, and 100 percent for model years 2007, 2008, and 2009 and later, respectively. Manufacturers may choose to average emission levels from engines required to meet the 16.0 g/kW-hr HC+NOx standard on a corporate basis; however, the emission levels for engines required to meet the 5.0 g/kW-hr HC+NOx standard may not be averaged.

Staff proposes to keep the existing 16.0 g/kW-hr HC+NOx averaged standard for model years 2003 through 2006. Beginning with the 2007 model year, however, staff proposes that manufacturers be allowed to choose from two implementation options that achieve emission benefits equivalent to those of the existing regulation.

The first option would allow manufacturers to comply with the standards and implementation schedules provided by the existing regulation. This is necessary to avoid penalizing manufacturers who might have already altered business practices and devoted resources towards meeting the existing requirements.

The second option would allow manufacturers to comply with an overall less stringent fixed standard of 14.0 g/kW-hr HC+NOx in 2007, followed by full implementation of the 5.0 g/kW-hr HC+NOx standard for 2008 and later model years. Although this option accelerates the full penetration of the catalyst-based 5.0 g/kW-hr HC+NOx standard one year ahead of the existing schedule, an emissions shortfall results for the 2007 model year. To compensate for this shortfall, manufacturers would be required to make up the difference with some other form of emissions control technology. Staff believes that the most likely approach to be employed by industry for achieving these supplemental emission benefits will be evaporative emission control since U.S. EPA has announced its intent to require evaporative emission control in its final rulemaking for inboard and sterndrive engines.

Additionally, staff is proposing that manufacturers may average engines with power ratings greater than 373 kW with those less than 373 kW (which must also meet a fixed 5.0 g/kW-hr HC+NOx standard) beginning with the 2009 model year. In so doing, manufacturers may be able to avoid the expense of having to equip high-power engines with catalysts should they be able to certify the remainder of their engines to sufficiently low emission levels.

Staff's proposed implementation options are summarized below:

OPTION 1: Certify to the existing Inboard/Sterndrive requirements, which require 45 percent of engines sold in model year 2007 and 75 percent of engines sold in model year 2008 to comply with a 5.0 g/kW-hr HC+NOx standard;

OPTION 2: Certify all engines to a fixed exhaust emission standard of 14.0 g/kW-hr HC+NOx in 2007 and replace the fuel tank supply/return hose with a low-permeation evaporative control hose with no more than 15.0 grams per square meter per day permeation rate on CE10[5] fuel at 23º Celsius, or otherwise incorporate another verifiable and quantifiable technique for achieving equivalent emission reductions. In 2008, certify all engines with rated power equal to or less than 373 kW to a fixed exhaust standard of 5.0 g/kW-hr HC+NOx with durability of 480 hours or 10 years, and carryover or upgrade the supplemental emissions technology from 2007.

Table 3.1 below illustrates staff's proposed amended exhaust standards for inboard and sterndrive engines including the necessary supplemental reductions required for Option 2. These supplemental reductions would most likely be achieved through evaporative emission control; however, other techniques for achieving the supplemental inventory reduction would also be acceptable so long as the reduction was quantifiable and verifiable. Regardless of the technique used to achieve the supplemental inventory reductions in 2007, it must continue to be used (carried-over) for all future model years unless a more stringent form of supplemental emissions control is required or is voluntarily incorporated into the design of the engine.

[5] CE10 fuel is an "American Society of Testing and Materials" (ASTM) standardized blend of 45% toluene, 45% iso-octane, and 10% ethanol

Table 3.1
Proposed Inboard/Sterndrive Marine Engine Standards

<table>
<tr><th rowspan="3">MODEL YEAR</th><th rowspan="2">RATED POWER</th><th rowspan="3">COMPLIANCE OPTION[1]</th><th rowspan="2">DURABILITY</th><th colspan="2">EXHAUST STANDARD</th><th rowspan="3">SUPPLEMENTAL MEASURE[3]</th></tr>
<tr><th>NMHC[2]+NOx</th><th rowspan="2">TYPE</th></tr>
<tr><th>[kilowatts]</th><th>[hours / years]</th><th>[grams per kilowatt-hour]</th></tr>
<tr><td>2003 - 2006</td><td>kW ≤ 373</td><td>N/A</td><td>N/A</td><td>16.0</td><td>AVE</td><td>None</td></tr>
<tr><td rowspan="3">2007</td><td rowspan="3">kW ≤ 373</td><td rowspan="2">OPT 1</td><td>N/A</td><td>16.0 (55%)</td><td>AVE</td><td rowspan="2">None</td></tr>
<tr><td>480 / 10</td><td>5.0 (45%)</td><td>FIXED</td></tr>
<tr><td>OPT 2</td><td>N/A</td><td>14.0</td><td>FIXED</td><td>Evaporative
Low-Permeation
Liquid Hoses</td></tr>
<tr><td rowspan="3">2008</td><td rowspan="3">kW ≤ 373</td><td rowspan="2">OPT 1</td><td>N/A</td><td>16.0 (25%)</td><td>AVE</td><td rowspan="2">None</td></tr>
<tr><td>480 / 10</td><td>5.0 (75%)</td><td>FIXED</td></tr>
<tr><td>OPT 2</td><td>480 / 10</td><td>5.0</td><td>FIXED</td><td>Evaporative
Low-Permeation
Liquid Hoses</td></tr>
<tr><td rowspan="3">2009 and later</td><td>kW ≤ 373</td><td rowspan="3">N/A</td><td>480 / 10</td><td>5.0[5]</td><td>FIXED</td><td rowspan="3">Carryover[6]</td></tr>
<tr><td>373 < kW ≤ 485</td><td>480 / 10</td><td>5.0[5]</td><td>AVE</td></tr>
<tr><td>kW > 485</td><td>50[4] / 1</td><td>5.0[5]</td><td>AVE</td></tr>
</table>

Notes:
1. Once a manufacturer has chosen an option, that option must continue to be used exclusively across product lines
2. The non-methane component of hydrocarbon
3. Supplemental measures may be different than shown, but must provide equal and verifiable emission reductions to those indicated
4. Engine manufacturers may request a shorter durability period for high power engines provided they submit data supporting a shorter period
5. All engines ≤ 373 kW must meet a 5.0 g/kW-hr NMHC+NOx capping standard. For engines > 373 kW, the standard may be met by sales-averaging with engines equal to or less than 373 kW
6. The same or better supplemental emission control hardware used to meet the standard in 2007 must be used every model year thereafter

3.3.1. Durability Period for Engines ≥ 485 kW

Staff is proposing to shorten the durability period for engines with power ratings greater than 485 kW (650 horsepower). Industry has contended that these high-power marine engines are generally rebuilt long before the existing durability period of 480 hours has occurred. According to industry, the reference engines for high power inboard and sterndrive engines are not meant to be used in conventional automotive applications and are often sold without a manufacturer warranty. They are typically used to power drag-racing type vehicles. Further, the marine manufacturer usually replaces various assemblies on these reference engines with high performance specialty parts to achieve higher power output than for which the reference engine was originally designed. Therefore, based on this information, and recommendations by the marine manufacturers to service various core components on engines with rated power greater than 485 kW after every 50 hours of use as stated in manufacturer provided service manuals, staff proposes to lower the durability period for engines with rated power greater than 485 kW to 50 hours or one year, whichever occurs first. Should an engine manufacturer believe that a shorter durability period is appropriate for a specific application with rated power greater than 485 kW, the manufacturer may request that the Executive Officer permit a shorter durability interval provided that the manufacturer support the request with documentation showing that a large volume of that application is being rebuilt more frequently than the established durability period. The previous Table 3.1 illustrates staff's proposed durability intervals.

3.3.2. Optional Default Emissions Level for Engines ≥ 485 kW

Further, for engines with rated power levels greater than 485 kW, staff is proposing to allow manufacturers the option to use either actual test data or a default emissions value of 30.0 g/kW-hr HC+NOx for the purposes of certification. Manufacturers choosing to certify using this default value would still be required to comply with a 5.0 g/kW-hr HC+NOx standard across product lines by "averaging in" the default value for its high-power engines with the actual emissions measurements from its engines with rated power less than 485 kW. Emission measurements, conducted by U.S. EPA and Mercury Marine, of engines ranging in power from 391 kW to 802 kW have varied from approximately 12.5 g/kW-hr to 25.9 g/kW-hr HC+NOx on the standard E4 certification test cycle (DATA E and DATA M). Staff believes that the proposed default value is a conservative estimate with regards to emissions, and would likely result in an un-quantified emissions benefit since the real emission levels for the majority of high-power engines would be well under 30.0 g/kW-hr HC+NOx. Still, the proposal should provide relief to the many manufacturers of engines with power levels greater than 485 kW that do not have access to emissions test facilities capable of accommodating such high-power engines, or who do not want to commit resources towards upgrading existing facilities.

3.4. Marine On-Board Diagnostics (OBD-M)

Although the marine industry has requested that the catalyst monitoring portion of the OBD-M requirements be delayed until 2012, staff proposes to retain the existing schedule for implementation which corresponds to the introduction of engines meeting the 5.0 g/kW-hr HC+NOx standard. Under the existing regulation, OBD-M is required on 5.0 g/kW-hr engines beginning with the 2007 model year. Based on staff's proposal to allow postponed compliance with the 5.0 g/kW-hr HC+NOx standard until the 2008 model year (Option 2), OBD-M would therefore also be postponed until the 2008 model year.

Further, all relief provisions built into the original regulation will remain applicable for the same durations originally specified. For example, the existing provision exempting manufacturers from having to incorporate OBD-M diagnostics for up to two years beginning in 2007 should the existing on-board computer not be capable of supporting all OBD-M diagnostics will begin in 2008 for engines certified to Option 2, and so on. As a consequence, the sum of existing relief provisions resulting from staff's proposed revisions would, in effect, give the industry what they have asked for. Specifically, staff's amendments would not require a fully compliant catalyst monitor until the 2012 model year under Option 1 or until the 2013 model year under Option 2. A more detailed explanation of staff's position regarding OBD-M can be found in subsection 4.2.1 of this report under the discussion on technological feasibility.

3.5. Labeling

Staff proposes to change the issuing requirement of the 4-star "super ultra low emissions" label, which was adopted by the Board during the 2001 rulemaking, to correspond to any inboard or sterndrive engine meeting the 5.0 g/kW-hr standard regardless of date. Currently, only 2007 and later engines complying with the 5.0 g/kW-hr standard can display the 4-star label. Staff believes that removing the date constraint of the 4-star label will provide additional incentive for the marine industry to introduce cleaner engines earlier than required.

3.6. In-Use Compliance Program

Staff proposes to retain the existing structure of the in-use compliance program as adopted by the Board during the 2001 rulemaking, but to revise the commencement date such that manufacturers certifying under Option 2 are subject to demonstrating that their 2008 and later engines will comply with the emission standards throughout their useful lives. The existing (Option 1) requirements are applicable only to post-2008 engines because the 5.0 g/kW-hr HC+NOx standard would not have been fully phased-in until 2009 under the existing regulation. Since staff is proposing that the 5.0 g/kW-hr HC+NOx standard be completely phased-in with the 2008 model year under Option 2, the in-use compliance program should also be applicable for 2008 models under that option.

3.7. Selective Enforcement Audit (SEA)

Staff proposes to exempt engines with rated power greater than 485 kW that have been certified to the optional default emissions level of 30.0 g/kW-hr from SEA applicability. However, engines of any power rating that have been certified with actual emissions test data shall remain subject to the SEA requirements.

3.8. Defects Warranty Provisions and Emission Control Warranty Statement

Staff proposes to accelerate the three year warranty period adopted by the Board during the 2001 rulemaking to begin in 2008 for Option 2, but to retain 2009 as the commencement date for Option 1, as required by the existing regulations. This maintains staff's original intention to correlate the three year warranty to the first year that the 5.0 g/kW-hr HC+NOx standard was fully implemented across product lines. Additionally, staff proposes to limit the warranty of mechanical engine head components such as valves and seats on engines with rated power greater than 485 kW to one year, or to 50 hours if equipped with an integrated electronic control module (ECM) hour-meter. These components typically require servicing at the stated intervals due to accelerated wear resulting from the high power output of these engines. All other emissions-related components such as sensors, injectors, and the ECM itself must continue to be warranted for three years.

4. DISCUSSION

4.1. Implementation Options and Supplemental Reductions

As previously stated, staff's objective in developing the proposed amendments to the existing Inboard/Sterndrive regulation was to provide industry with additional lead-time for complying with the catalyst-driven 5.0 g/kW-hr HC+NOx exhaust standard while preserving the emission benefits of the existing regulation. Accordingly, staff is proposing that engine manufacturers be allowed to choose between two implementation options, the first retaining the implementation schedule of the existing regulation and the second providing a one year delay of the 5.0 g/kW-hr HC+NOx standard in exchange for supplemental emission reductions and an accelerated implementation schedule the following year.

To provide more flexibility, staff is proposing that manufacturers be allowed to use any verifiable method for generating the supplemental emission reductions required under Option 2 so long as that method is sufficient to compensate for the emissions shortfall in 2007 that arises from relaxing the 5.0 g/kW-hr HC+NOx standard for that year. However, staff believes that the most likely form of supplemental emissions control to be employed by the marine industry will be the replacement of the fuel tank supply/return hose with a low-permeation evaporative loss control hose. This would be a relatively simple, low-cost, and durable solution to the supplemental emissions reduction requirement. Furthermore, U.S. EPA has indicated that it will most likely require low-permeation evaporative control hoses for inboard and sterndrive engines in its final rulemaking tentatively scheduled for 2007. At present, U.S. EPA is contemplating a permeation standard of 15.0 g/m^2/day[6] for liquid carrying hoses. This would provide an estimated 85 percent reduction over nitrile rubber based hoses, which are most commonly used in inboard and sterndrive pleasurecraft, and for which a 100.0 g/m^2/day[7] reference standard has been established by the Society of Automotive Engineers (SAE J1527). Staff expects that many engine manufacturers will use some form of evaporative emissions control to comply with the proposed Option 2 since they would soon after be required to incorporate evaporative standards anyway due to the federal rule (see the Appendix for additional information on evaporative permeation).

Table 4.1 shows ARB's off-road inventory database estimates for staff's proposed Option 2 without any supplemental emissions benefit offsets. If employed exclusively by industry, the option would result in a statewide exhaust emissions shortfall in 2007 of 0.7 tons per day ROG+NOx (shaded box in Table 4.1) based on summer weekend only

[6] Based on operation at 23º Celsius and CE10 fuel - 45% toluene, 45% iso-octane, and 10% ethanol.
[7] Based on ASTM D471-98 standardized Fuel C for nitrile rubber hoses.

operation. Therefore, in order to use Option 2 (14.0 g/kW-hr HC+NOx standard in 2007) a manufacturer would have to incorporate additional emission control technology to make up its portion of the lost benefit.

Table 4.1
Existing (Option 1) vs. Proposed Option 2 Inboard/Sterndrive Exhaust Emission Inventories
Statewide Summer Weekend

ENGINE TYPE	POLLUTANT	EXHAUST EMISSIONS INVENTORY [tons per day]								
		2007			2010			2020		
		OPT 1	OPT 2	Δ	OPT 1	OPT 2	Δ	OPT 1	OPT 2	Δ
STERNDRIVE	ROG[1]	36.7	36.7	0.0	35.8	35.6	0.2[2]	31.0	30.9	0.1[2]
	NOx	42.3	42.7	(0.4)	41.4	41.5	(0.1)	37.5	37.5	0.0
	ROG[1]+NOx	79.0	79.4	(0.4)	77.2	77.1	0.1[2]	68.5	68.4	0.1[2]
INBOARD[3]	ROG[1]	29.8	29.6	0.2[2]	29.1	28.9	0.2[2]	24.4	24.4	0.0
	NOx	34.7	35.2	(0.5)	34.2	34.4	(0.2)	30.2	30.2	0.0
	ROG[1]+NOx	64.5	64.8	(0.3)	63.3	63.3	0.0	54.6	54.6	0.0
TOTAL	ROG[1]	66.5	66.3	0.2[2]	64.9	64.5	0.4[2]	55.4	55.3	0.1[2]
	NOx	77.0	77.9	(0.9)	75.6	75.9	(0.3)	67.7	67.7	0.0
	ROG[1]+NOx	143.5	144.2	(0.7)	140.5	140.4	0.1[2]	123.1	123.0	0.1[2]

Notes:
1 ARB inventory estimates are expressed as the reactive organic gas (ROG) component of hydrocarbon
2 Parenthetical values in the delta "Δ" column indicate a net (loss) in emission benefits for Opt 2 compared to existing estimates
3 This engine classification also includes recreational spark-ignition jet drive engines

Table 4.2 shows the benefits from using a 15.0 g/m^2/day low-permeation hose on the fuel tank supply/return line for the 2007 model year only, and assuming that all manufacturers choose Option 2. Benefits would decrease proportionately should some manufacturers choose to implement Option 1, but never to the extent that they would fall below the projected benefits of the existing regulation. However, actual emission benefits could be much larger than indicated for the 2010 and 2020 model years since staff's proposal would require manufacturers choosing Option 2 to continue employing the same or better supplemental emissions control technology (low-permeation hose) for all subsequent model years.

Table 4.2
Supplemental Reductions for Option 2
Statewide Summer Weekend

MODEL YEAR	INVENTORY DISPARITY[1] [tons per day]	SUPPLEMENTAL REDUCTIONS[2] [tons per day]		NET BENEFITS [tons per day]
	ROG[3]+NOx	ROG[3]	NOx	ROG[3]+NOx
2007	(0.7)	0.9[4]	-	0.2
2010	0.1	0.6[4,5]	-	0.7
2020	0.1	0.2[4,5]	-	0.3

Notes:
1 ARB projected (loss) or gain in benefits from postponing the 5.0 g/kW-hr HC+NOx standard from 2007 to 2008
2 Assuming all manufacturers will use 15 g/m^2/day low-permeation liquid fuel supply/return hoses
3 ARB inventory estimates are expressed as the reactive organic gas (ROG) component of hydrocarbon
4 The estimated benefit for California Inboard/Sterndrive engines based on recent U.S. EPA modeling
5 Benefits are based on engine population attrition and 10% permeation degradation per year

According to recent modeling of evaporative emissions by U.S. EPA[8], the effect of all manufacturers using a 15.0 g/m^2/day low-permeation fuel tank supply/return hose on California's inboard and sterndrive engines in 2007 would result in a benefit of 0.9 tons per day ROG statewide during the summer months, thereby increasing the overall net statewide reduction of combined ROG and NOx emissions by 0.2 tons per day.

4.2. Technological Feasibility

The technological feasibility of the existing Inboard/Sterndrive regulation has already been established by staff in its report to the Board during the 2001 rulemaking and follow-up test programs at SwRI. Namely, the technologies previously determined feasible were leaner air-fuel calibration, electronic fuel injection, oxygen sensor feedback fuel control, catalytic converters, and, by automotive reference, on-board diagnostics. However, Option 2 of staff's proposed amendments would likely necessitate the incorporation of an additional emission control component that was not demonstrated during that rulemaking. Low-permeation evaporative loss control hoses have been used successfully by the automotive industry (ARB 1998b) for many years and are currently required for use on other applications such as lawnmowers (ARB 2003) and highway motorcycles (RSD 2003). The ARB rulemakings for light- and medium-duty passenger vehicles and small off-road engines (i.e., lawnmowers) clearly established the feasibility of low-permeation hoses for the control of evaporative emissions. The low-permeation hoses suggested as a means for providing supplemental emission reductions in this report are expected to have similar material

[8] Evaporative estimates are based on August 2005 U.S. EPA permeation modeling (RSD 2002). These estimates have been refined since their original release in 2002 to more accurately reflect the California population distribution of inboard and sterndrive engines.

specifications. The durability of low-permeation hoses was also established as part of those rulemakings[9].

4.2.1. On-Board Diagnostics (OBD) and Post-Catalyst Oxygen Sensors

OBD is a collection of subroutines and algorithms integrated into the on-board computer of an electronically controlled engine to monitor and evaluate the performance of emission-related components and systems under actual operating conditions. When a malfunction is detected, the OBD system alerts the engine operator, typically by illuminating a warning light, and stores codes and other information so that the malfunction can be easily identified and fixed properly. OBD was first required on light-duty and medium-duty passenger vehicles in 1991. A second, more comprehensive version, known as OBD II, became effective in 1996, and has been required on all new passenger vehicles ever since. In 2001 the Board adopted OBD-M (or OBD-Marine) requirements as part of the Inboard/Sterndrive rulemaking. The introduction of OBD-M is scheduled to coincide with engines certifying to the 5.0 g/kW-hr HC+NOx standard. Since inboard and sterndrive engines are nearly identical to their on-road counterparts, OBD-M was a logical progression. Many of the required OBD-M algorithms can be transferred from on-road technology and, in fact, many are already built into existing inboard and sterndrive computer controllers. OBD-M is meant to ensure the proper performance of emission-related components and systems on inboard and sterndrive engines throughout their useful lives and to facilitate their maintenance when necessary.

The OBD-M requirements went through several revisions during the development of the inboard and sterndrive regulation in 2001. The final adopted version significantly reduced the burden on marine manufacturers to incorporate complicated monitoring strategies in response to their concerns regarding the availability of resources. For example, misfire monitoring was relegated to a conditional requirement - only to be required if necessary to protect the catalytic converter. Further, manufacturers were allowed to delay illumination of the malfunction indicator light (MIL) for oxygen sensors, the catalyst, and the fuel system until the 2009 model year. This delay provides manufacturers with additional lead-time to gain field experience to perfect the required diagnostic strategies. Furthermore, the decision to delay illumination of the MIL shields the consumer from any potential false detection by the OBD-M system during the first few years of the program.

Another element that spares manufacturer resources and facilitates compliance is the provision allowing manufacturers to certify their systems with monitors that fall short of meeting the full requirement of the regulation. Up to three “deficiencies,” as these partial monitoring strategies are called, can be claimed by the manufacturer for an engine family without cost, so long as the manufacturer makes a good faith effort to meet the requirements. Further, the manufacturer would be granted up to three years

[9] The staff reports (see references ARB 1998b and ARB 2000) are available and may be downloaded from the Air Resources Board website at http://www.arb.ca.gov.

to bring the deficient monitoring strategies into full compliance with the OBD-M regulation.

Although the overwhelming majority of OBD-M strategies can be directly transferred from existing automotive OBD technology, the level of precision required of the OBD-M system to detect malfunctions is far less rigorous than for OBD-II on-road applications. The malfunction detection thresholds for automotive OBD systems are generally calibrated to a 50 or 75 percent increase in emissions, but OBD-M allows manufacturers to set their own thresholds for identifying malfunctions, within reason. This degree of flexibility represents a considerable savings in both time and money, since calibrations can be set to more convenient specifications that match off-the-shelf hardware and software.

Currently, the marine industry's primary concern regarding OBD-M is the development of a reliable and cost-effective catalyst monitor. This issue was raised during the development of the inboard and sterndrive regulation in 2001, at which time the marine industry contended that the conventional automotive technique of using oxygen sensors to monitor the catalytic converter might not be easily transferable to the marine environment due to the susceptibility of oxygen sensors to water. Although compelling data in support of this claim have yet to be made available, ARB responded to industry's concern by revising the catalyst monitoring requirement to allow other monitoring methods including uncomplicated temperature-based algorithms. The option for marine manufacturers to use oxygen sensors would also be allowed if they so prefer.

Off-the-shelf automotive grade temperature methods of catalyst monitoring may not be as readily available as oxygen sensor methods, due to the predominance of the automotive industry to use less expensive oxygen sensor methods. Nevertheless, the temperature feedback method is viable and has been investigated in great detail by several sensor suppliers and automotive manufacturers, with at least one SAE paper devoted to the subject, "Closed Loop Temperature Feedback for Controlled Catalyst Light-off and Diagnostics for ULEV" (SAE 1999). The OBD-M application of such a temperature based method for catalyst monitoring should be far less rigorous than the intended automotive application (which is the subject of the SAE paper), due to the less stringent OBD-M requirements.

Because of cost and a proven "track record," marine manufacturers will likely use the oxygen sensor method to satisfy the OBD-M requirements. In the staff's 2004 briefing to the Board on the Fresh-Water Safety and Durability Program conducted by SwRI in 2002 (see subsection 4.2.2), it was clearly shown that oxygen sensors located upstream of the catalysts were durable for the useful life of the engine (480 hours). For oxygen sensors located downstream of the catalyst, the marine industry has raised concerns that the sensors would be damaged due to water reversion. However, as demonstrated during the Fresh-Water Safety and Durability Program, the potential adverse impacts due to water reversion can be eliminated with a properly designed exhaust system. Nevertheless, if industry remains concerned over the oxygen sensor's potential exposure to water, they could opt to place the oxygen sensor between the bricks of a catalyst (mid-bed). This could be used to satisfy the catalyst monitoring requirements of the OBD-M regulation. Some automotive manufacturers have used such a mid-bed technique successfully for years. All of this evidence suggests that catalyst monitoring using oxygen sensors or temperature-based methods should be feasible within the constraints of the current OBD-M regulation (Authorization 2005).

4.2.2. 2002 Fresh-Water Safety and Durability Program

As part of the 2001 rulemaking, Board Resolution 01-23 directed staff to collaborate with industry for the purpose of demonstrating that catalysts are safe and durable when used in the marine environment. Efforts to conduct a test program using catalysts began in 2002. ARB funded the project, which was carried out with the assistance of the National Marine Manufacturers Association (which provided boats and engines) and the Manufacturers of Emission Controls Association (which provided catalysts and other emission control components). The United States Coast Guard supplied the fuel and provided operators for the boats to accumulate the desired 480 hours (i.e., useful life) of “on water” use. SwRI was contracted to conduct the test program, which included fabricating new exhaust systems (to accommodate the exhaust catalysts) and sampling the exhaust emissions. As reported to the Board at the October 2004 Public Meeting, this test program successfully demonstrated that catalysts are safe and durable when operated on freshwater (SwRI 2004). Currently a second, similar project is underway to determine the effect(s), if any, that saltwater may have on the exhaust catalysts and other emission control components (see subsection 4.2.3).

The test program confirmed that the emission control system performed properly and safely without incident. Upon successful completion of 480 hours of “on-water” operation, the boats were returned to SwRI. The engines were removed from the boats and installed in a test cell for emission testing. Compared to zero-hour baseline testing, some deterioration of the emission levels is expected after 480 hours of use. Staff was very pleased to learn however, that although demonstrating compliance to the 5.0 g/kW-hr HC+NOx standard was not the aim of this project, deterioration was low and all three 5.7L engines remained under that emission level, several years ahead of when needed to meet the standards.

With the goal of demonstrating the safety and durability of catalysts, the project was successful. There were no instances of fire or excessive heat, and the results from both the on-water and in-laboratory exhaust sampling show that catalysts are robust in the marine environment. Another notable success was the upstream oxygen sensors. These prototype sensors were designed with a shrouded tip, to make them less prone to water damage. Throughout the course of the on-water accumulation, these sensors remained undamaged and did not require replacement.

4.2.3. 2005 Salt-Water Test Program

Another test program funded jointly by ARB and U.S. EPA is currently underway to determine the durability of catalysts and the feasibility of monitoring the catalytic converter in a saltwater environment. Again, this project is being conducted in conjunction with the marine industry and SwRI has been hired as the contractor. The United States Coast Guard is also, again, supplying the fuel for the project, and the Texas Parks and Wildlife Department has volunteered to operate the boats. The goal is to operate the engines on water for as long as possible up to 480 hours; however, given the time constraints of the test program and the scheduled implementation of catalyst-based standards, it is possible that less than 300 hours may actually be accumulated. Extrapolated data will be used to project durability to the 480 hour endpoint. The engines will be tested periodically to determine whether or nor emissions performance has been compromised due to the saltwater and whether or not the hardware necessary to support OBD-M catalyst monitoring remains viable throughout the 480 hour accumulation period. Staff intends to provide a summary of available results in its presentation to the Board at the November 17-18, 2005, Board Hearing.

Staff believes that the results of this program will ultimately show similar durability for catalysts and oxygen sensors as did the fresh water test program. By comparison, ARB certification records show that at least one personal watercraft (PWC) manufacturer has been successfully using catalysts on a two-stroke engine since 2001. ARB Executive Order U-W-003-0085 can be viewed online at the ARB website[10]. This PWC operates in both freshwater and saltwater. About 200 of these PWCs are sold annually in California and 2,000 nationwide. Warranty claims for defective catalysts are virtually nonexistent for this manufacturer. By design, two-stroke engines produce much more rapid and pronounced fluctuations in exhaust pressure than the four-stroke engines of inboard and sterndrive vessels. As such, water reversion should be a greater challenge for the PWC manufacturer, yet the lack of catalyst warranty claims indicates that it has not been an issue. Furthermore, catalysts on two-stroke PWC engines also have to contend with the ingestion of lubricating oil, which should have a much higher potential for poisoning the catalyst than saltwater reversion, yet this also has not been an obstacle to compliance.

4.3. Safety Concerns

Staff is unaware of any safety-related issues being raised by the marine industry at this time regarding staff's proposed amendments to the regulation. However, with the likely incorporation of catalyzed materials in the exhaust stream to meet the 5.0 g/kW-hr HC+NOx standard, there is the potential for increased heat dissipation. However, this issue was addressed during the Freshwater Safety and Durability Program, which found that the use of catalysts is not likely to pose any threat to the safety of vessel occupants (SwRI 2004).

[10] http://arb.ca.gov/msprog/offroad/cert/2005/sime_05/u-w-003-0085.pdf

5. ENVIRONMENTAL IMPACTS AND COST-EFFECTIVENESS

The intent of staff's proposal is to provide industry with a choice of compliance flexibility options that preserve the emissions reduction goals of the existing regulation. In crafting the proposed options (explained in subsection 3.3), staff worked to ensure that the emission benefits projected as a result of the existing regulation would not be adversely affected. With respect to Option 1, which maintains the status quo in model years 2007 and 2008, it is obvious that no net change in emission reductions will occur. However, Option 2, which allows manufacturers to certify to a less stringent exhaust emissions standard in 2007 in exchange for accelerated compliance to the 5.0 g/kW-hr standard in 2008, has the potential to provide emission reductions in excess of those projected under the existing regulation. Therefore, regardless of which option each manufacturer chooses, or the mix of options that the manufacturers collectively choose, no adverse environmental impacts are expected as a result of staff's proposal.

5.1. Projected ROG+NOx Emission Benefits

A summary of emission benefits from staff's proposal is shown in Table 5.1. Since Option 1 requires the same standards and implementation schedule as the existing requirements, no net gain in benefits occurs. However, should manufacturers choose to comply with Option 2 using a low-permeation fuel tank supply/return hose, staff projects that some additional reductions could result as indicated in Table 5.1. The table also shows that the combined ROG+NOx emissions from inboard and sterndrive marine engines are reduced by about 57 tons of ROG+NOx per day in 2020 based on a summer weekend average, compared to unregulated engines. As documented in the 2001 Inboard/Sterndrive staff report, this reduction is equivalent to eliminating the exhaust emitted by approximately 1.6 million passenger vehicles.

Table 5.1
Projected Emission Benefits for Inboard[1] and Sterndrive Engines
Statewide Summer Weekend

MODEL YEAR	POLLUTANT	EMISSION BENEFITS [tons per day]			
		Option 1 (Existing)[2]	Option 2[3]	Gains[4]	
				Option 1	Option 2
2007	ROG+NOx	0.8	1.0	0.0	0.2
2010	ROG+NOx	12.2	12.9	0.0	0.7
2020	ROG+NOx	56.8	57.1	0.0	0.3

Notes:
1 This engine classification also includes recreational spark-ignition jet drive engines
2 Existing benefits differ slightly from 2001 estimates due to recent modeling refinements
3 Option 2 benefits include evaporative reductions from a low-permeation fuel tank supply/return hose
4 The gain in emission benefits vs. existing requirements (optional)

5.2. Carbon Monoxide (CO) Benefits

CO emissions from inboard and sterndrive pleasurecraft are also a concern. The United States Coast Guard and the National Institute for Occupational Safety and Health warn against the practices of wakeboarding and teak surfing because of the potential for these activities to result in serious injury or death as a result of CO inhalation from close proximity to the boat engine's exhaust. Typically, CO poisoning occurs while wakeboarders and teak surfers hold on to the back of the boat at idle or low cruising speeds. From 1990-2004, there were 43 boat-related CO poisoning cases in California according to a Boating Accident Report published by the United States Coast Guard (USCG 2004).

While ultimately staff intends to propose a CO standard for inboard and sterndrive pleasurecraft, testing is still underway to determine an appropriate level of emissions that will be sufficient to protect public health and to achieve attainment with air quality standards. Furthermore, U.S. EPA intends to promulgate a CO standard (U.S. EPA 2002) for inboard and sterndrive engines in a final rulemaking tentatively scheduled for 2007. If and when the federal CO standard is promulgated, staff will prepare to return to the Board requesting the adoption of a harmonized CO standard in California if appropriate.

With respect to staff's proposal to allow standard averaging in 2009 (subsection 3.3), which could potentially enable engines greater than 373 kW to comply with the regulation without a catalyst, staff believes the potential for these engines to be used for wakeboarding, teak surfing, or other "tow sports" is extremely low. Boats with these high power engines typically contain two engines and are on the order of 33 feet in length. The wake created by them is generally prohibitive of "tow sports" including water skiing, unless an extremely long rope (100 feet) is used. Boats with these engines are purchased primarily for racing activities.

Although the regulations at this time do not include CO standards, staff believes that significant reductions in CO will occur regardless as a result of industry's migration to three-way catalysts in 2008. Staff estimates that reductions in CO on the order of 40 to 80 percent below existing levels (150 to 200 g/kW-hr) are reasonable to expect since passenger vehicle catalysts are typically 90+ percent efficient in reducing CO.

5.3. State Implementation Plan (SIP)

The existing inboard and sterndrive marine engine regulations were adopted by the Board in 2001 and have been included as part of the baseline for SIP revisions since 2002. The emissions from this source category are most significant during the summer ozone season. Some of the changes proposed by staff could impact current SIP commitments. Staff's proposed amendments to the regulations provide the marine industry with two compliance options for model years 2007 and 2008. These options provide additional flexibility in that they allow manufacturers the opportunity to choose a path to compliance that is best suited to individual production roll-out goals. The emissions and SIP impacts of the proposed amendments are dependent on which alternative is chosen, but none is expected to have a negative impact on SIP commitments.

Option 1 of staff's proposal allows manufacturers to continue meeting the requirements of the existing regulation for model years 2007 and 2008, and would result in no change in the timing or amount of emission reductions. Option 2 allows marine manufacturers to meet a less stringent exhaust standard (14.0 g/kW-hr HC+NOx) in 2007 with full compliance to the 5.0 g/kW-hr HC+NOx standard in 2008, one year earlier than currently required. Option 2 also requires supplemental emission reductions in 2007 to compensate for the less stringent exhaust standard in that model year. Given that the most likely approach for achieving the supplemental emissions reduction would be with evaporative emissions control, Option 2 has the potential to reduce combined HC and NOx emissions below existing projected levels (see Tables 4.1 and 4.2). However, the ratio of HC to NOx in the emission reductions could change (e.g., Option 2 with evaporative control would result in decreased HC emissions and slightly increased NOx emissions compared to the existing requirements).

Even though the overall HC+NOx emissions would be the same or even lower, the slight change in the relative amounts of HC and NOx could have an impact on ozone and secondary particulate matter formation. The direction and magnitude of the impact is unknown, but likely very small. Only the portion of MY 2007 engines certified to Option 2 with evaporative control would have the higher NOx emissions. However, these engines would have lower HC emissions, which would provide the additional benefit of lowering emissions of toxic substances from gasoline evaporation, such as benzene and toluene.

By 2020, emission levels under the proposed amendments would be at or below levels required by the existing regulation, thus preserving or enhancing the long-term SIP benefits. If the Board approves these amendments, any emission impacts arising from their implementation will be reflected in the next round of SIPs.

5.4. Environmental Justice

State law defines environmental justice as the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies (Senate Bill 115, Solis; Stats 1999, Ch. 690; Government Code § 65040.12(c)). The Board has established a framework for incorporating environmental justice into ARB's programs consistent with the directives of State law. The policies developed apply to all communities in California, but recognize that environmental justice issues have been raised more in the context of low income and minority communities, which sometimes experience higher exposures to some pollutants as a result of the cumulative impacts of air pollution from multiple mobile, commercial, industrial, area-wide, and other sources. Over the past twenty years, ARB, local air districts, and federal air pollution control programs have made substantial progress towards improving the air quality in California. However, some communities continue to experience higher exposures than others as a result of the cumulative impacts of air pollution from multiple mobile and stationary sources and thus may suffer a disproportionate level of adverse health effects. Since the same ambient air quality standards apply to all regions of the State, all communities, including environmental justice communities, will benefit from the air quality benefits associated with the proposal. As additional relevant scientific evidence becomes available, the spark-ignition inboard and sterndrive marine engine standards will be reviewed again to make certain that public health is protected with an adequate margin of safety.

To ensure that everyone has had an opportunity to stay informed and participate fully in developing these proposed amendments to the spark-ignition inboard and sterndrive marine engine standards, staff has had meetings and has participated in public forums as described in subsection 2.6 of this report.

5.5. Cost-Effectiveness

The cost-effectiveness found in the 2001 rulemaking was $2.08 to 3.39/lb HC+NOx reduced (ARB 2001). Staff expects no net change in cost-effectiveness from that found in the 2001 rulemaking, because the proposed amendments, in addition to providing an option for delaying catalyst-based standards, also provide a choice for the engine manufacturer to continue complying with the existing regulation. Presumably, a manufacturer would choose the new option only if it was within its financial interests to do so. Therefore, the existing regulation remains an upper bound for cost-effectiveness. If low-permeation evaporative emission control hoses are utilized as a means of complying with the regulation, the slight increase in costs to the manufacturer ($0.40 to $0.60 per foot per a 6 foot hose on average) should be offset by the savings resulting from the relaxation of requirements to introduce engines meeting the catalyst-based 5.0 g/kW-hr HC+NOx standard prior to 2008.

6. ECONOMIC IMPACTS

The proposed regulatory amendments are not expected to result in net additional costs above the costs to comply with the existing regulation. Adoption of staff's proposal is actually expected to benefit engine manufacturers by providing them with additional lead-time to comply with the catalyst forcing 5.0 g/kW-hr HC+NOx standard that they would not otherwise have under the existing regulation. Therefore, staff maintains that the proposed amendments would have no adverse impacts on business competitiveness, California employment, or on business creation, elimination, and expansion. Furthermore, if any manufacturer determines that compliance with the existing regulation is more economically advantageous than staff's proposed amendments, that manufacturer is still able to choose to comply with the existing regulation. This section discusses, in greater detail, the potential cost and economic impacts of staff's proposed amendments.

6.1. Legal Requirement

Sections 11346.3 and 11346.5 of the Government Code require State agencies to assess the potential for adverse economic impacts on California business enterprises and individuals when proposing to adopt or amend any administrative regulation. The assessment shall include a consideration of the impact of the proposed regulation on California jobs, business expansion, elimination, or creation, and the ability of California business to compete.

State agencies are required to estimate the cost or savings to any state or local agency, and school districts. The estimate is to include any nondiscretionary cost or savings to local agencies and the cost or savings in federal funding to the state.

6.2. Affected Businesses

Staff does not expect any business to be adversely affected by the proposed amendments to the regulation, including those pertaining to farm or agriculture. Staff's amendments would provide additional lead-time and greater flexibility for any marine engine manufacturer or boat builder to comply with the regulation. Boat owners are not likely to be adversely affected because inboard and sterndrive pleasurecraft are primarily used in recreational applications and are not typically employed to support the livelihood of California residents. The amendments are directed at manufacturers, so docks, ports, and fishing and boating stores are not expected to be adversely affected by staff's proposal; in fact, the amendments may indirectly benefit them since the amendments are meant to provide relief to the marine industry.

6.2.1. Estimated Costs to Engine Manufacturers

If a manufacturer chooses to comply with staff's proposed Option 2, a slight increase in costs to the manufacturer could occur if it chooses to incorporate low-permeation evaporative tubing ($0.40 - $0.60 per foot for a 6 foot hose on average). However, this incremental cost will be more than offset by the relaxation of requirements to introduce engines equipped with catalytic converters prior to 2008. Further, manufacturers may still choose Option 1 (see subsection 3.3) that allows them to continue following the existing standards and implementation schedule if desired, which would result in no change in costs to engine manufacturers.

6.2.2. Potential Impacts on Business

Staff does not expect any business to be adversely affected by the proposed amendments to the regulation. The evaporative control technology to be incorporated under Option 2, is readily available, generally inexpensive, and does not require special expertise to install. In addition, a manufacturer will be able to choose if that is the option it wishes to follow. On the other hand, the proposed amendments are likely to benefit manufacturers because they provide additional compliance flexibility and lead-time to comply with the regulation. Inboard and sterndrive engines are primarily used in recreational applications and do not typically support the livelihood of California residents. As mentioned above, the amendments are directed at manufacturers, so docks, ports, and fishing and boating stores are not expected to be adversely affected by staff's proposal; in fact, the amendments may indirectly benefit them since the amendments are meant to provide relief to the marine industry. Further, proposed Option 1 (see subsection 3.3) allows manufacturers to continue following the existing standards and implementation schedule if desired, which would result in no change in economic impacts on businesses.

6.2.3. Potential Impact on Business Competitiveness

The proposed amendments are not expected to have a significant impact on the ability of California businesses to compete with businesses in other states since any engine produced in, or imported into, the State must comply with the proposed requirements. Staff does not expect that any business will suffer a competitive disadvantage from the proposed amendments. The evaporative control technology to be incorporated under Option 2, if selected by the engine manufacturer, is readily available, generally inexpensive, and does not require special expertise to install. Inboard and sterndrive engines are primarily used in recreational applications and do not typically support the livelihood of California residents. As noted previously, docks, ports, and fishing and boating stores are not expected to be adversely affected by staff's proposal, since the amendments are directed at manufacturers. To the extent that the amendments provide relief to the marine industry, the docks, ports, and fishing and boating stores could also benefit. Manufacturers may still choose Option 1 (see subsection 3.3) that allows them to continue following the existing standards and implementation schedule if desired, which would result in no change on business competitiveness.

6.2.4. Potential Impact on Employment

The proposed amendments are not expected to cause a noticeable change in California employment. The evaporative control technology to be incorporated under Option 2, if selected by the engine manufacturer, is readily available, generally inexpensive, and does not require special expertise to install. The adoption of staff's proposal is expected to benefit manufacturers, who would otherwise have to equip a portion of their engines with catalysts and on-board diagnostics one year sooner. Further, proposed Option 1 (see subsection 3.3) allows manufacturers to continue following the existing standards and implementation schedule if desired, which would result in no change in employment.

6.2.5. Potential Impact on Business Creation, Elimination or Expansion

The proposed amendments are not expected to have a noticeable impact on the status of California business creation, elimination, or expansion. The evaporative control technology to be incorporated under Option 2, if selected by the engine manufacturer, is readily available, generally inexpensive, and does not require special expertise to install. Manufacturers may still choose Option 1 (see subsection 3.3) that allows them to continue following the existing standards and implementation schedule if desired, which would result in no change in business creation, elimination, or expansion.

6.2.6. Potential Impact on Small Businesses

The proposed amendments are not expected to have a noticeable impact on the status of California businesses including small businesses. The evaporative control technology to be incorporated under Option 2, if selected by the engine manufacturer, is readily available, generally inexpensive, and does not require special expertise to install. Manufacturers may still choose Option 1 (see subsection 3.3) that allows them to continue following the existing standards and implementation schedule if desired, which would result in no impact on small businesses.

6.3. Potential Costs to Local and State Agencies

Staff believes the proposed requirements are the most cost-effective means of achieving emission reductions of the same magnitude as the existing regulation. The proposed amendments are not expected to result in an overall increase in costs for State or local agencies. The proposed amendments are not expected to increase workload or impact the current ARB budget. Any administrative costs related to the implementation of staff's proposed amendments would be absorbed with existing ARB resources. ARB is already responsible for verifying the implementation of the existing regulations for inboard and sterndrive, as well as other marine spark-ignition engines.

7. REGULATORY ALTERNATIVES

The staff evaluated various alternatives to the current proposal. A brief description of the alternatives and staff's rationale for finding them unsuitable follows below.

7.1. Preserve Existing California Regulations

The first alternative to this proposal would be to simply keep the existing California Inboard/Sterndrive regulations. Although staff's proposal includes allowing manufacturers to continue complying with the existing regulation, the proposed amendments also provide industry with options for additional flexibility while achieving equivalent emission benefits, and the potential to achieve additional emission benefits in Option 2. The existing regulation does not offer compliance flexibility options and may unnecessarily burden some segments of the marine industry. Therefore, staff rejected this alternative.

7.2. Wait for the Adoption of Federal Regulations

Although U.S. EPA has published a Notice of Proposed Rulemaking for inboard and sterndrive engine standards, a federal regulation is not expected to be promulgated until 2007 or implemented prior to 2009 at the earliest. Considering that California has had regulations in place since 2001, and that staff's proposed amendments preserve the emission benefits of those requirements, postponing these amendments would only serve to deny reasonable relief to the regulated industry.

The advantage of a national regulation is harmonization. Manufacturers would have to comply with only one set of regulations for all nationwide sales. The disadvantage of relying on the federal rulemaking is largely one of uncertainty and timing. Staff fully intends to continue working with U.S. EPA in its development of a federal rule to ensure consistency of standards and other requirements. If after the federal rule has been promulgated, staff determines that additional amendments will help achieve harmonization without harming the California program, staff will return to the Board with additional amendments. However, delaying action until the federal regulation is finalized would unnecessarily burden the marine industry. Therefore, staff rejected this alternative.

7.3. Accelerate Implementation of Standards

Staff examined the possibility of accelerating the implementation schedule of standards to get cleaner engines into California earlier. While this alternative would provide emission benefits sooner, manufacturers would have less lead-time to develop the necessary emission control technologies, and manufacturers would have fewer years over which to spread out and recoup the development expenses. This would also make the proposal far less cost-effective. Therefore, staff rejected this alternative.

8. FUTURE PLANS

8.1. CO Standard

As previously noted in subsection 5.2, although this proposal does not include a CO standard for inboard and sterndrive pleasurecraft, it is ultimately staff's intention to propose a CO standard. Furthermore, U.S. EPA intends to promulgate a CO standard (U.S. EPA 2002) for inboard and sterndrive engines in a final rulemaking tentatively scheduled for 2007. If and when the federal CO standard is promulgated, staff will prepare to return to the Board requesting the adoption of a harmonized CO standard in California if appropriate.

8.2. Evaporative Standards

Although staff is proposing to allow the use of low-permeation evaporative control to achieve the supplemental emission reductions required under compliance Option 2 (see subsection 3.3), no additional formal requirement to address evaporative emissions is being proposed at this time. U.S. EPA is currently developing evaporative standards to be promulgated federally on inboard and sterndrive engines in a final rulemaking tentatively scheduled for 2007. Staff expects that many engine manufacturers will use some form of evaporative emissions control to comply with the proposed Option 2 since they would soon after be required to incorporate evaporative standards anyway due to the federal rule. As appropriate, staff will return to the Board requesting the adoption of harmonized evaporative emission control standards after the final U.S. EPA rule has been published.

8.3. High Power Engines (> 373 kW)

Industry has asked for relief regarding the certification of, and the incorporation of catalysts on, high-power inboard and sterndrive engines. The primary reason for this request is the high cost (estimated $500,000) that would be incurred by individual engine manufacturers in purchasing the emissions sampling equipment necessary to test high-power engines. Flow rates and other test parameters on high-power engines often exceed the capacity of existing sampling equipment and have the potential to damage equipment in addition to rendering inaccurate measurements. Staff has responded to industry's request by proposing that engines with rated power greater than 485 kW be allowed to certify to a default emissions value of 30.0 g/kW-hr HC+NOx in lieu of having to generate actual test data. Further, staff is proposing that engines with rated power greater than 373 kW be allowed to average emission levels with lower power engines for the purpose of complying with the 5.0 g/kW-hr standard. However, staff is aware that the proposed averaging relief provision may not be adequate for some manufacturers whose product lines consist primarily or exclusively of engines with rated power greater than 373 kW. For these manufacturers, staff is still considering the best approach for providing relief. Since engines with rated power greater than 373 kW are exempt from certification requirements until model year 2009, staff intends to return to the Board prior to that date with a proposed resolution to this issue.

9. CONCLUSIONS AND RECOMMENDATIONS

Staff's objective in recommending the inclusion of additional compliance options into the Inboard/Sterndrive regulation is to provide reasonable relief for the marine industry while preserving, and possibly increasing, air quality benefits compared to existing inventory projections. The estimated California cost-effectiveness with adoption of the staff's proposal remains $2.08 to 3.39/lb HC+NOx reduced as calculated for the 2001 rulemaking. This cost-effectiveness is well within the range of other control measures adopted by the Board.

No alternative considered by the agency would be more effective in carrying out the purpose for which the amended regulation is proposed, or would be as effective as, or less burdensome, to affected private persons than the proposed regulation. Therefore, staff recommends that the Board adopt staff's proposal as contained in this report and noted in the attached proposed regulations and test procedures.

10. REFERENCES

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ARB 1998b: California Air Resources Board, Proposed Amendments to California Exhaust and Evaporative Emission Standards and Test Procedures for Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles, September 18, 1998 (Staff Report).

ARB 2001: California Air Resources Board, Public Hearing to Consider Adoption of Emission Standards and Test Procedures for New 2003 and Later Spark-Ignition Inboard and Sterndrive Marine Engines, June 8, 2001 (Staff Report).

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U.S. EPA 1997: United States Environmental Protection Agency, Control of Emissions of Air Pollution From Highway Heavy-Duty Engines; Final Rule, 62 Federal Register 54694-54730, October 21, 1997.

U.S. EPA 2002: United States Environmental Protection Agency, Control of Emissions from Spark-Ignition Marine Vessels and Highway Motorcycles; Notice of Proposed Rulemaking, 67 Federal Register 53050-53115, August 14, 2002.

APPENDIX: MODELING THEORY AND REFERENCE SPECIFICATIONS FOR VARIOUS LOW-PERMEATION EVAPORATIVE EMISSION CONTROL MATERIALS

Evaporative permeation is the rate at which liquid or gaseous hydrocarbon penetrates the material used to contain it (e.g., hoses, fuel tanks, etc.). It is usually quantified as the mass rate of diffusion per unit of time in grams per day (g/day). For the purposes of normalization and setting standards, permeation rates are further divided by the contact surface area and width of a material in order to be used as a reference for that specific type of material. For example, to calculate the permeation rate of a 6 foot long fuel supply hose with a 3/8 inch inner diameter, first find the inner surface area of the hose by multiplying its inner diameter by pi and then again by the length of the tube. After converting to SI units, this results in a contact surface of 0.055 m^2. Multiply this by the baseline permeation rate of the hose, typically 100 $g/m^2/day$ for spark-ignition engines according to SAE J1527 and U.S. EPA modeling - although this number can fluctuate throughout the year due to changes in ambient temperature or the Reid vapor pressure of the fuel - and the result is the daily amount of hydrocarbon that hose releases to the atmosphere due to permeation (5.5 g/day). In the same example, if a low-permeation hose (15 $g/m^2/day$) of similar dimensions were used, the permeation rate would only be 0.83 g/day resulting in a net benefit of 4.7 g/day.

Table A.1 shows the permeation rates for various materials used in the construction of vacuum and liquid hoses for vehicular and marine engine applications. Here, the thickness of the low-permeation material in millimeters is factored into reference specification. Hoses made from fluoroelastomers provide a reasonable compromise between permeation control and cost, and would be a good choice for complying with the supplemental emission reduction requirements of staff's proposed Option 2. The shaded row in the table identifies the fluoroelastomer FKM Viton GLT. This material has been manufactured using 65 percent fluorination and, with a 14 $g\text{-}mm/m^2/day$ permeation rate, would comply with the requirements for a supplemental emission control technology under Option 2 of staff's proposal. It should be noted, however, that this low-permeation material provides an even greater barrier to evaporative loss when Fuel C[11] is used, about one-half the permeation rate associated with the CE10[12] reference fuel (RSD 2003). Fuel C is similar to gasoline regarding permeation; therefore hoses made from this material should be able to control permeation on inboard and sterndrive engines to an even greater degree than Table A.1 specifications indicate. The cost of FKM Viton GLT is approximately $0.40 to $0.60 per foot and is typically applied as a one millimeter thick liner or layer within a hose made of more permeable material.

[11] Fuel blend consisting of 50% toluene and 50% iso-octane (ASTM D471-98)
[12] Fuel blend consisting of 45% toluene, 45% iso-octane, and 10% ethanol

Table A.1
Fuel System Material Permeation Rates at 23º Celsius by Fuel Type[1]

MATERIAL NAME	COMPOSITION	FUEL C[2]	FUEL CE10[3]	CM15[4]
		[grams-millimeter / m^2 / day]		
HDPE	high density polyethylene	35	-	35
Nylon 12, rigid	thermoplastic	0.2	-	64
EVOH	ethylene vinyl alcohol, thermoplastic	-	-	10
Polyacetal	thermoplastic	-	-	3.1
PBT	polybutylene terephthalate, thermoplastic	-	-	0.4
PVDF	polyvinylidene fluoride, fluorothermoplastic	-	-	0.2
NBR (33% ACN)	nitrile rubber	669	1028	1188
HNBR (44%ACN)	hydrogenated nitrile rubber	230	553	828
FVMQ	flourosilicone	455	584	635
FKM Viton A200 (66%F)	fluoroelastomer	0.80	7.5	36
FKM Viton B70 (66%F)	fluoroelastomer	0.80	6.7	32
FKM Viton GLT (65%F)	fluoroelastomer	2.60	14	60
FKM Viton B200 (68%F)	fluoroelastomer	0.70	4.1	12
FKM Viton GF (70%F)	fluoroelastomer	0.70	1.1	3.0
FKM Viton GFLT (67%F)	fluoroelastomer	1.80	6.5	14
FKM - 2120	fluoroelastomer	8	-	44
FKM - 5830	fluoroelastomer	1.1	-	8
Teflon FEP 1000L	fluorothermoplastic		0.03	0.03
Teflon PTFE	polytetrafluoroethylene, fluoroplastic	-	-	0.05
Teflon PFA 1000LP	fluorothermoplastic	0.18	0.03	0.13
Tefzel ETFE 1000LZ	ethylene-tetrafluoro-ethylene, fluoroplastic	0.03	0.05	0.20
Nylon 12 (GM grade)	thermoplastic	6.0	24	83
Nitrile	nitrile	130	635	1150
Silicone Rubber	silicone rubber	-	-	6500
Fluorosilicone	fluorosilicone	-	-	635
FKM	fluoroelastomer	-	16	-
FE 5620Q (65.9% fluorine)	fluorothermoplastic	-	7	-
FE 5840Q (70.2% fluorine)	fluorothermoplastic	-	4	-
PTFE	polytetrafluoroethylene, fluoroplastic	0.05	-	0.08[5]
ETFE	ethylene-tetrafluoro-ethylene, fluoroplastic	0.02	-	0.04[5]
PFA	fluorothermoplastic	0.01	-	0.05[5]
THV 500	tetra-fluoro-ethylene, hexa-fluoro-propylene, vinyledene fluoride	0.03	-	0.3

Notes:
1. From 2003 U.S. EPA Final Regulatory Support Document: Control of Emissions from Highway Motorcycles (RSD 2003)
2. Fuel blend consisting of 50% toluene and 50% iso-octane (ASTM D 471-98)
3. Fuel blend consisting of 90% Fuel C and 10% ethanol
4. Fuel blend consisting of 85% Fuel C and 15% methanol
5. Tested on a fuel blend of 80% Fuel C and 20% methanol (CM20)

ATTACHMENT A: PROPOSED AMENDMENTS TO THE CALIFORNIA REGULATIONS FOR NEW 2007 AND LATER SPARK-IGNITION INBOARD/STERNDRIVE PLEASURECRAFT

ATTACHMENT B: PROPOSED AMENDMENTS TO THE CALIFORNIA EXHAUST EMISSION STANDARDS AND TEST PROCEDURES FOR 2001 MODEL YEAR AND LATER SPARK-IGNITION MARINE ENGINES